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## **Ultrasound Machine ‘Knobology’**

### **Abstract**

Being a ‘real time’ imaging modality, ultrasound images are almost always interpreted by the operator at the time of examination. Obtaining optimal image quality throughout the scan is therefore essential to maximise the clinical information that can be obtained. This article aims to discuss the main control features that are likely to be present on most machines, such as gain, depth and focal points, as well as some other options that may be available to the operator, such as tissue harmonic imaging and speckle reduction. Examples of different settings are shown, with reference to how they may be optimised to obtain the best possible image quality.

### **Text:**

Unlike most other imaging modalities where all images acquired are digitally stored and available for future reference, ultrasound is a ‘real-time’ modality, where it is rare for an entire examination to be recorded. Retrospective interpretation is therefore very difficult, relying on assessment of a few saved frames or short clips in isolation, often without the benefit of information on position or orientation. Obtaining the best possible image quality at the time is therefore important, together with concurrent identification and interpretation of any changes observed.

The quality of images obtained is dependent on the skill of the operator, as well as the available equipment. Whatever the specification of equipment used, frequent manipulation of the controls during any examination is essential to maximise the information gained. Manufacturer ‘pre-sets’ (Figure 1) may be available for different

anatomical regions as a starting point for an examination; however image quality is a subjective assessment and users may have varying preferences, which can differ from the pre-set values.

Some of the later features discussed in this article will not be available on all equipment: check the user manual to identify the features present on any individual machine.

### **Overall Gain**

The overall gain control (Figure 2) adjusts the overall brightness of the image, similar to the brightness control on a computer monitor or television. The aim is to have the screen bright enough to see the image clearly, but not so bright that you start to see echogenicity within normally anechoic structures such as the urinary bladder or gallbladder. Reducing the gain slightly when scanning fluid-filled structures and increasing it when imaging solid organs may therefore be helpful. Ambient light levels will also influence the optimal gain, which will need to be higher when scanning in more brightly lit areas.

### **Time Gain Compensation**

Time Gain Compensation (TGC) controls (Figure 3) usually consist of a row of parallel slider buttons. The aim of these controls is to obtain an even brightness through the entire field of view. This is necessary because of the attenuation of the ultrasound beam as it travels through tissue, due to reflection, absorption and scattering. This attenuation means that reflections of sound from deeper structures are weaker than those from similar tissue interfaces positioned more superficially. Without TGC, the image would have a light to dark gradient, running from the near

field of the image to the far field. The sliders are typically set in a diagonal fashion from left to right, such that echoes coming from deeper within the animal are amplified more, to compensate for the reduced sound intensity in the far field. The setting of the slider controls is often reflected on the screen by a line paralleling the edge of the image.

## **Depth**

Every ultrasound machine displays a scale on the screen that marks image depth, usually in cm. The depth control allows the operator to manipulate the displayed depth. An independent 'zoom' control may also be available to enlarge a selected area of the image.

The depth setting should be changed according to the size of the animal and the organ being imaged. For example, to image the whole liver in a larger dog, you will need to see a relatively deep area (maybe 12-15cm), whereas when looking at more superficial structures, it may be adequate to only include the first 2-3cm of tissue. As a 'rule of thumb', adjust the depth of the image until the organ or area of interest fills approximately three quarters of your screen, to maximise the level of detail you see. Completely filling the screen with the structure of interest is not usually optimal, as useful artefacts such as shadowing or distal acoustic enhancement may be missed and anatomical relationships to adjacent structures become more difficult to determine.

Reducing the imaged depth has a small added advantage of increasing frame rate and therefore temporal resolution, as the machine will not have to 'wait' as long for echoes to return from deeper structures.

## **Focal zone(s)**

Although some machines may have automatic focussing, many have an adjustable focal zone, which is indicated by an arrowhead or other symbol along the depth scale. The focal zone setting indicates the point at which the ultrasound beam is narrowest width-wise and is therefore the point at which the best lateral resolution (across the image) is obtained. The focal zone should be set at, or just below the depth of the area of interest within your field of view; for example, if you are assessing a loop of small intestine, adjust the focal point so that it lies at this level (Figure 4).

It may be possible to set more than one focal zone (Figure 5), to increase the resolution at multiple depths within the image. This does come with the 'trade-off' of proportional slowing of the frame rate. This is because the ultrasound machine is now sending out multiple sound beams, each focussed to one of the focal zones. This takes more time and may lead to a 'slow motion' or lag effect on the image. For this reason, more than one focal zone is not recommended for cardiac scanning, where structures are moving relatively rapidly.

If a scanner does not show the focal zone with a marker, by convention the focus is around the middle of the image and it becomes necessary to change the depth to ensure that the structure(s) of interest are in the central section of the display.

## **Frequency**

Many transducers will operate at multiple frequencies and most ultrasound systems come with the option of several interchangeable transducer types. Increasing the output frequency leads to an increase in the axial resolution (top to bottom) of the image. However increasing the frequency does come with the 'trade-off' of reducing

penetration. Some machines will show the actual frequency (in MHz); others don't show the frequency and offer choices such as resolution ("Res") suitable for superficial imaging, general ("Gen") for moderate depths and penetration ("Pen") for deeper structures. The aim is always to use the highest possible frequency setting that allows you to assess the area of interest.

### **Image Orientation**

On most machines it is possible to flip and invert the image. 'Flipping' the image from right to left can be useful, either to obtain a conventional image orientation (*e.g.* cranial to the left) or, depending on operator preference, when performing ultrasound guided sampling procedures. However the same result can also be achieved by rotating the transducer through 180°. Inversion (such that the area immediately adjacent to the transducer lies in the far field of the display) may also be a selectable option, but is rarely helpful for veterinary applications.

### **Dynamic Range**

This control is sometimes 'buried' within menus but can be considered together with the B-mode gain and the grey scale map (see below). The higher the dynamic range is set, the greater the spread of echo strengths (and therefore 'shades of grey') between black and white. High dynamic range settings therefore make the image smoother and less contrasty, whereas low settings lead to a more black and white image (Figure 6). If scanning in a light room, it may help to lower the dynamic range setting to give higher contrast, as our ability to resolve subtle greyscale differences in bright light is relatively poor.

## **Grey Map**

Adjusting the grey map (Figure 7) has a similar effect on an ultrasound image as changing the dynamic range, but the mechanism is different. Whilst dynamic range adjusts the number of shades of grey, a grey map determines how brightly each level of white/grey is shown, based upon the strength of the returning ultrasound signal. Considering and adjusting dynamic range and grey scale in conjunction with each other may be the best approach to optimising image quality.

## **Output Power**

This is also a setting usually found in menus, rather than as a direct button on the control panel. The power setting is analogous to the volume of the sound in an ultrasound pulse. A stronger, louder pulse will generate stronger echoes, which is generally good. However higher power settings can lead to an increase in internal reflections, creating more artefacts such as reverberation. Higher power settings also lead to increased thermal and mechanical (e.g. cavitation) effects in tissue; this is a consideration for obstetric scanning as although the risk is very small, any potential biological effects are likely to be of greatest significance in the foetus. Any obstetric 'pre-sets' on a machine are therefore likely to have a relatively low power setting.

## **Harmonic Imaging**

Harmonic imaging helps to reduce artefacts and increase resolution in the image: it achieves this by sending and receiving signals at different ultrasound frequencies, with the returning frequency being a harmonic of the initial one. For example with harmonics on, a probe may emit a fundamental frequency of 4MHz, but would only "listen" for a returning 8MHz frequency.

A machine capable of harmonic imaging will have a “THI,” “Harm,” “HI,” or similar control on the machine. When it’s enabled, it is typically adjusted via the frequency control. If available, try imaging an area with and without the harmonic setting activated (Figure 8), to see if the image improves. As harmonic imaging was developed to reduce artefacts arising in the near field of large human patients with a thick body wall, it may have less application in smaller veterinary patients.

### **Speckle Reduction Imaging**

‘Speckle’ is seen in an ultrasound image as a granular pattern formed from constructive and destructive interference of backscattered ultrasound waves; it lowers image contrast and obscures detail. Various imaging techniques based on altering beam frequency, beam orientation (spatial compounding) and/or digital ‘filtering’ of the image have been applied to try to reduce speckle and improve image quality. Manufacturer specific names for this technique include SRI, SRI HD, XRes, iClear, MView, Adaptive Speckle Reduction, SCI, ApliPure+, SonoHD, TeraVision and SRF.

Machines that include this feature usually offer varying levels of Speckle Reduction (Figure 9). The lowest level reduces small amounts of artefact and lightly enhances tissue, while the strongest levels can look over-processed: a mid-level setting often provides the best results.

### **Frame Averaging/Persistence**

Frame averaging, or persistence, is a temporal smoothing function in which multiple image frames are combined, or “averaged” into a single image. The effect is similar to that of speckle reduction, in that the image appears smoother with reduced ‘noise



Decreasing persistence settings will create a more pixelated/speckled image, with a higher frame rate.

### **Compound Imaging**

This technique is also named differently by manufacturers, with names including CrossXBeam, CRI, SonoCT, iBeam, OmniBeam, XView, SonoMB, ApliPure and Spatial Compounding. A compound image combines three or more images acquired from different angles into a single view. This is achieved through an ultrasound transducer sending signals at multiple angles, which helps to eliminate artefact (including speckle) and increase edge detail. Compound Imaging is available only on linear and convex transducers, not on sector transducers.

### **Auto Optimisation**

Many machines come with a feature that analyses the returning signals from tissue and automatically optimises the gain and overall contrast of the image. Synonyms for this feature are Auto Tuning and Tissue Equalization. If your machine has this feature, try it, but also try changing things manually as well, as there may be further room for improvement.

### **Finally...**

If you make adjustments you like, most machines allow the saving of custom imaging presets; check the user manual to see how to do this.

If you make a disaster of the image, either reset to the original selected 'pre-set' from the initial menu or, as a last resort, it's all computer based, so try turning it off and on again!

## **Key Points**

- Maximising image quality is critical – even with ‘lower end’ equipment, understanding and manipulating the available settings can help improve the image.
- When scanning, as you move between different regions always think about displayed depth and gain (including time gain compensation), adjusting these to optimise the image for the area of interest.
- Always select the highest possible frequency setting that allows you to see to the depth of the structure of interest.
- If the focal point can be manually set, move it level with, or just deep to the main area of interest within the displayed image.
- Many other settings may be available – look at the user interface (keyboard and menus) and user manuals for your system to see what options are available and don’t be afraid to try them!

## **Key Words**

- Ultrasound
- Gain
- Depth
- Focal Point
- Veterinary

## **Figure Legends:**

**Figure 1:** Example of the range of pre-sets stored for one linear transducer: it is generally preferable to keep the manufacturer pre-sets and add customised ones (asterixed here) rather than to over-write them and lose the ability to restore settings.

**Figure 2:** Effect of increasing the overall gain setting, with increasing gain from left to right. Images show the spleen in the near field and intestine/mesenteric fat in the far field; the image on the left has the gain setting too low, and that on the right is too high. Optimum gain would be at, or slightly higher than the central image, depending on the ambient light levels and operator preference.

**Figure 3:** Time Gain compensation

(a) Sliding controls, set at a typical orientation with increased gain in the far field.

The position of the controls is indicated on the image by the white line to the right of the screen.

(b) Extreme adjustment of the TGC controls can lead to excessive changes in gain, as seen by the black band across the centre of this image and the high gain in the near and far fields.

**Figure 4:** Focal zone adjustment. Note the increased detail in the small intestinal layering and the abdominal wall when the focal zone is aligned with them (left) compared to the focal zone being in the far field (right). In this image, the displayed depth is set higher than would be optimal, for illustration purposes.

**Figure 5:** Image illustrating the proportional reduction in frame rate (circled) when the number of focal zones is increased from one to two. The level of the focal point(s) is indicated by arrowheads superimposed on the depth markings.

**Figure 6:** Image illustrating the effect of increasing the dynamic range setting: from left to right, settings are 40; 55; 65; 75; 90. Note the high contrast and increased edge detail on the lower settings, and the 'smoothing' of images as the dynamic range increases.

**Figure 7:** Grey map examples: note the change in pixel brightness between the different maps.

**Figure 8:** Harmonic imaging; the image on the left has harmonics turned off (general setting) and the image on the right has harmonics turned on ('THI'). Note the increased detail with harmonics on, noticeable in the improved clarity of the layering of the small intestinal loop (seen here lying deep to the spleen). The change in frequency from 9MHz to 11MHz was an automatic adjustment by the machine when switching to harmonic imaging.

**Figure 9:** Speckle reduction: the three cropped images of a feline spleen show no speckle reduction (left), a low setting (centre) and higher setting (right). Note the 'smoothing' of the image, with the splenic parenchyma becoming progressively less 'granular' in appearance.

**Further Reading:**

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Fetal Echo

MSK

Ped Abd

\*GENERAL ABDO

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Testis

Thyroid

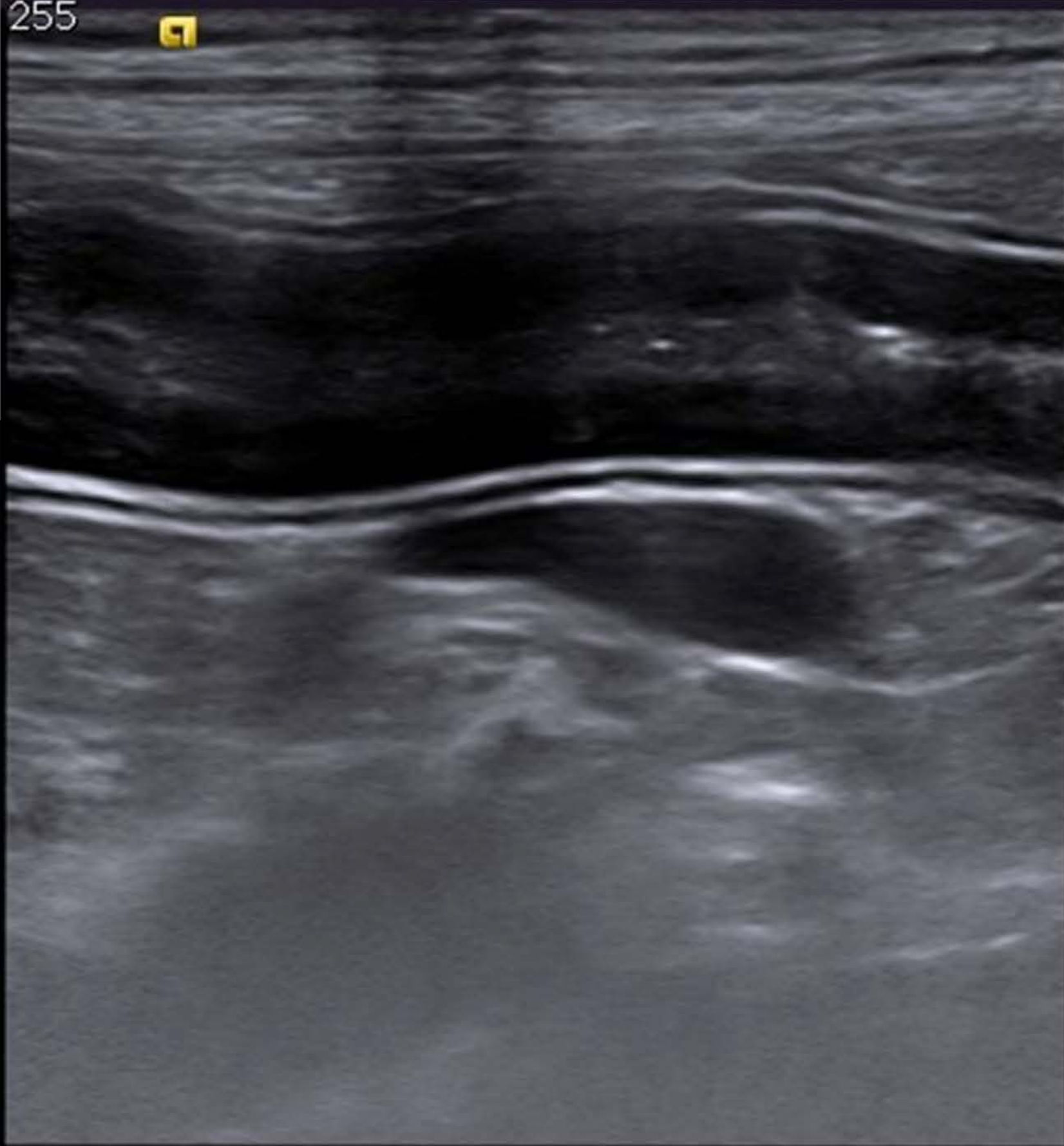
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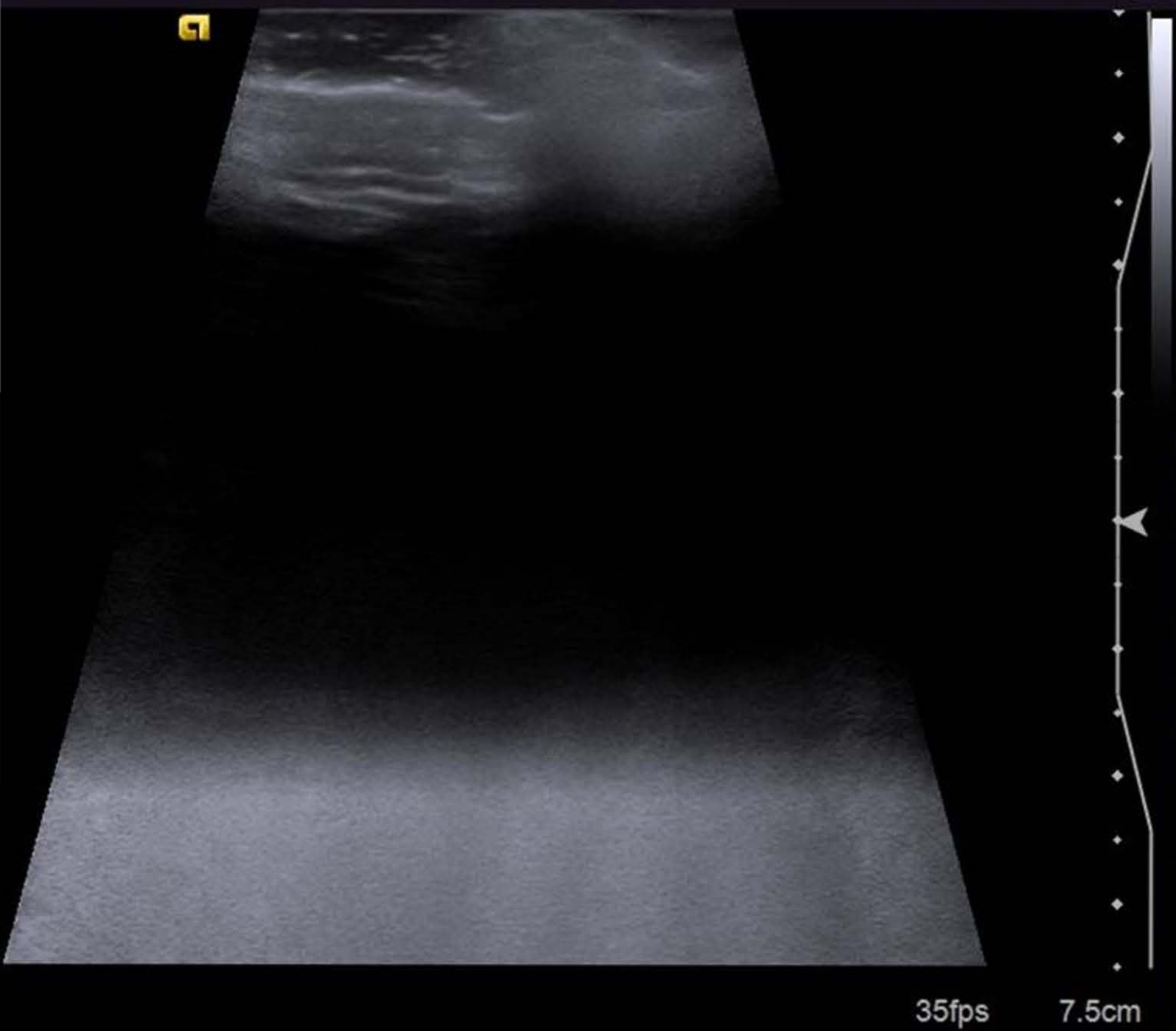




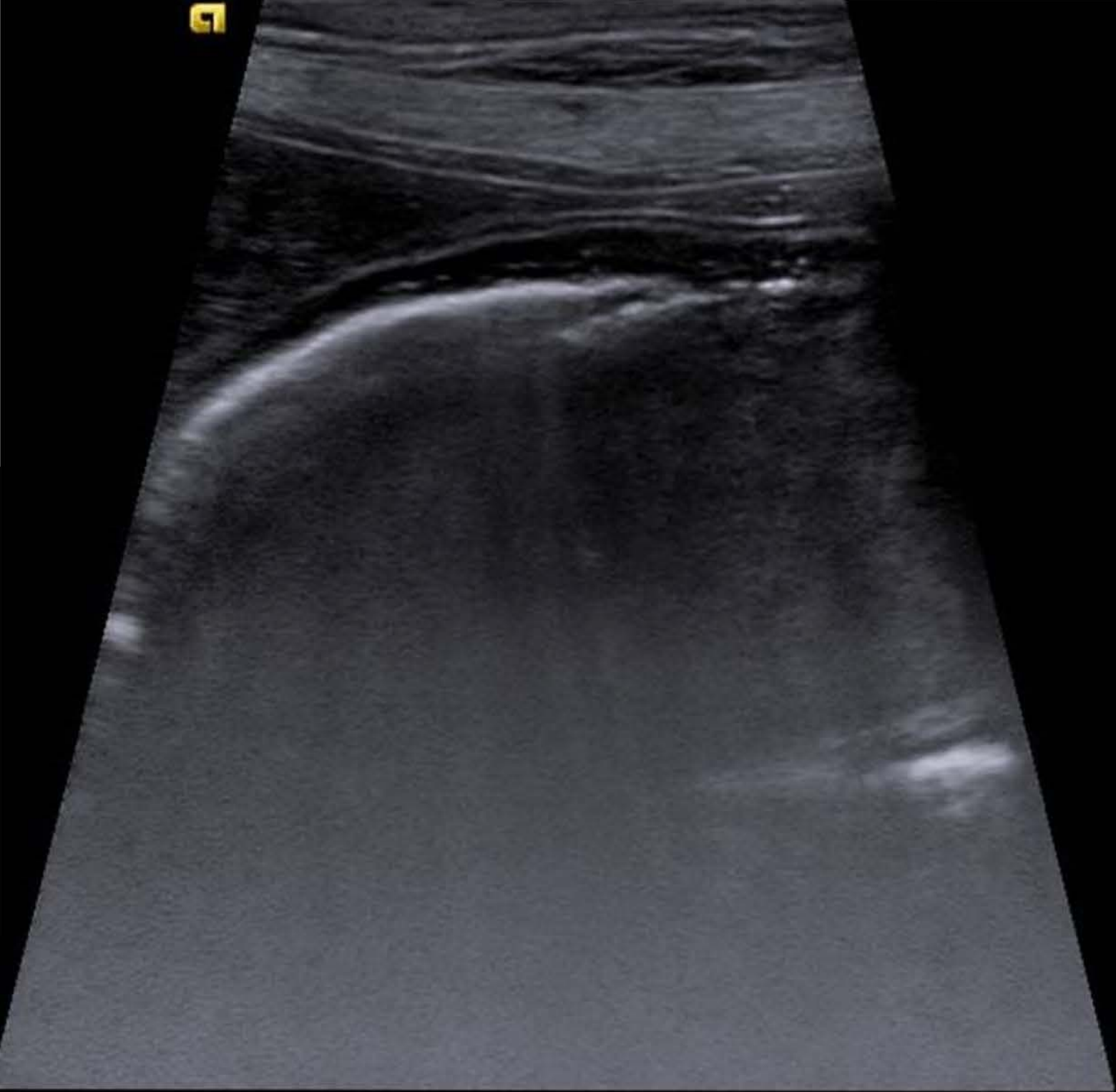




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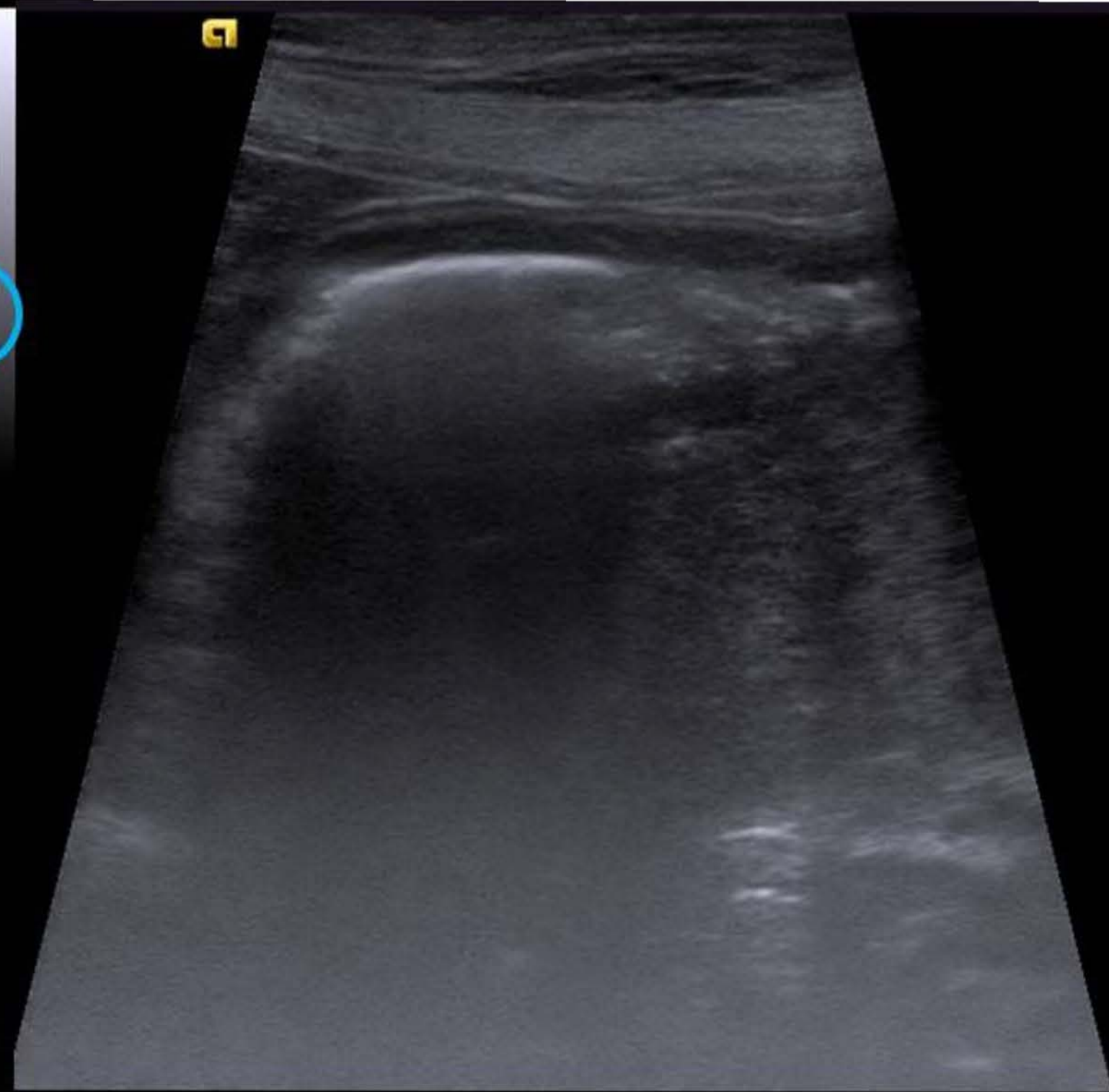






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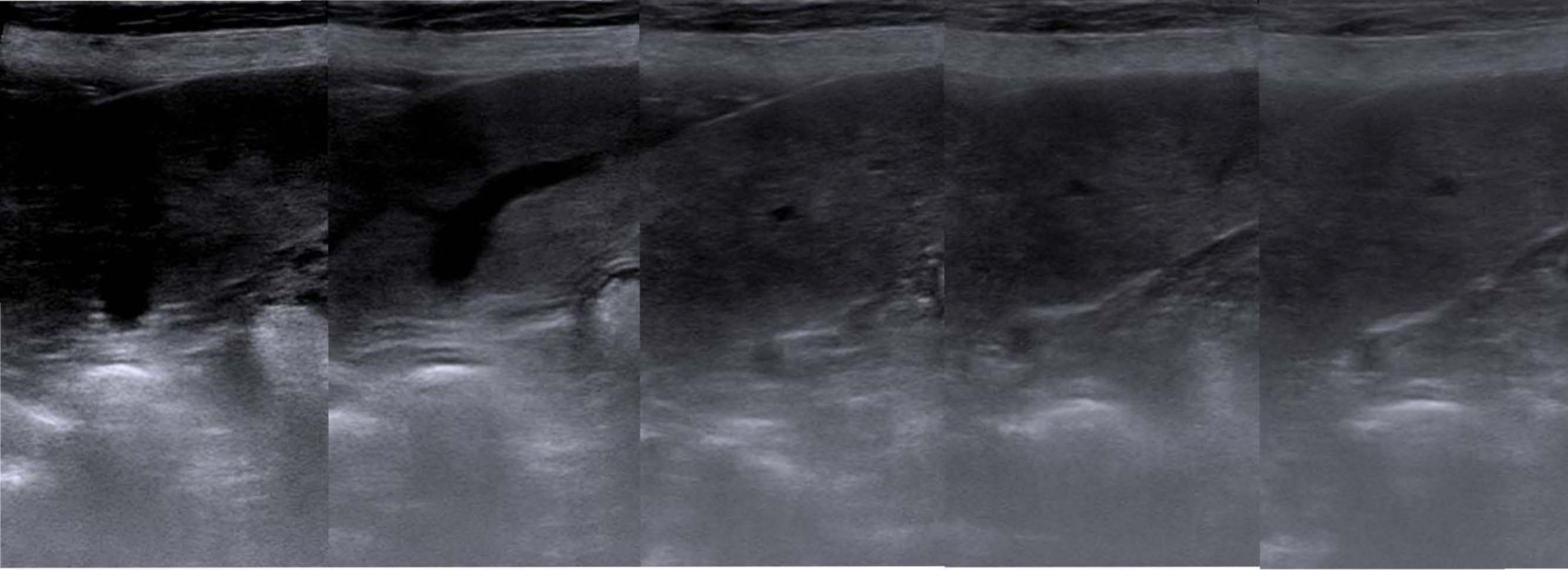


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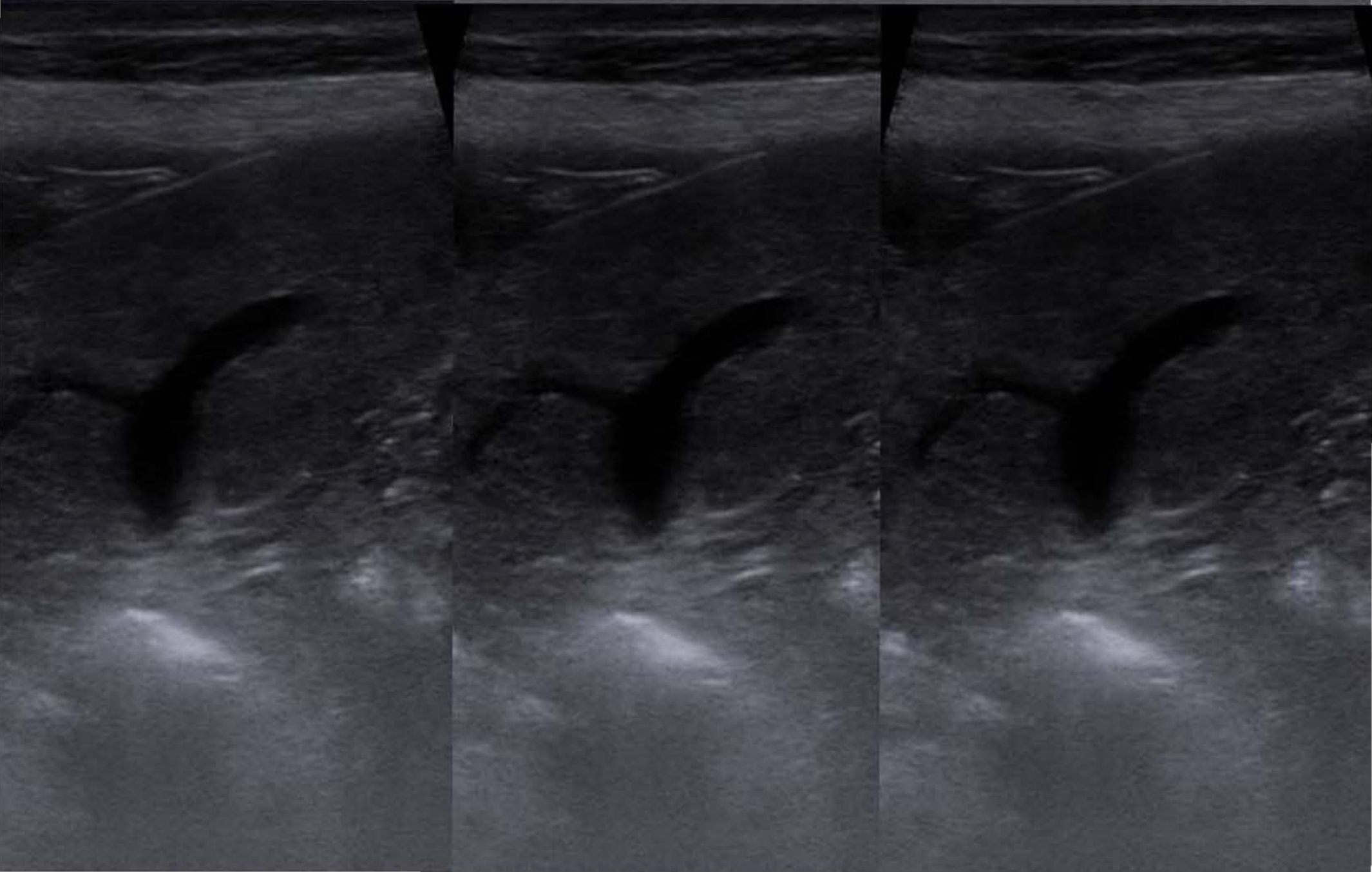
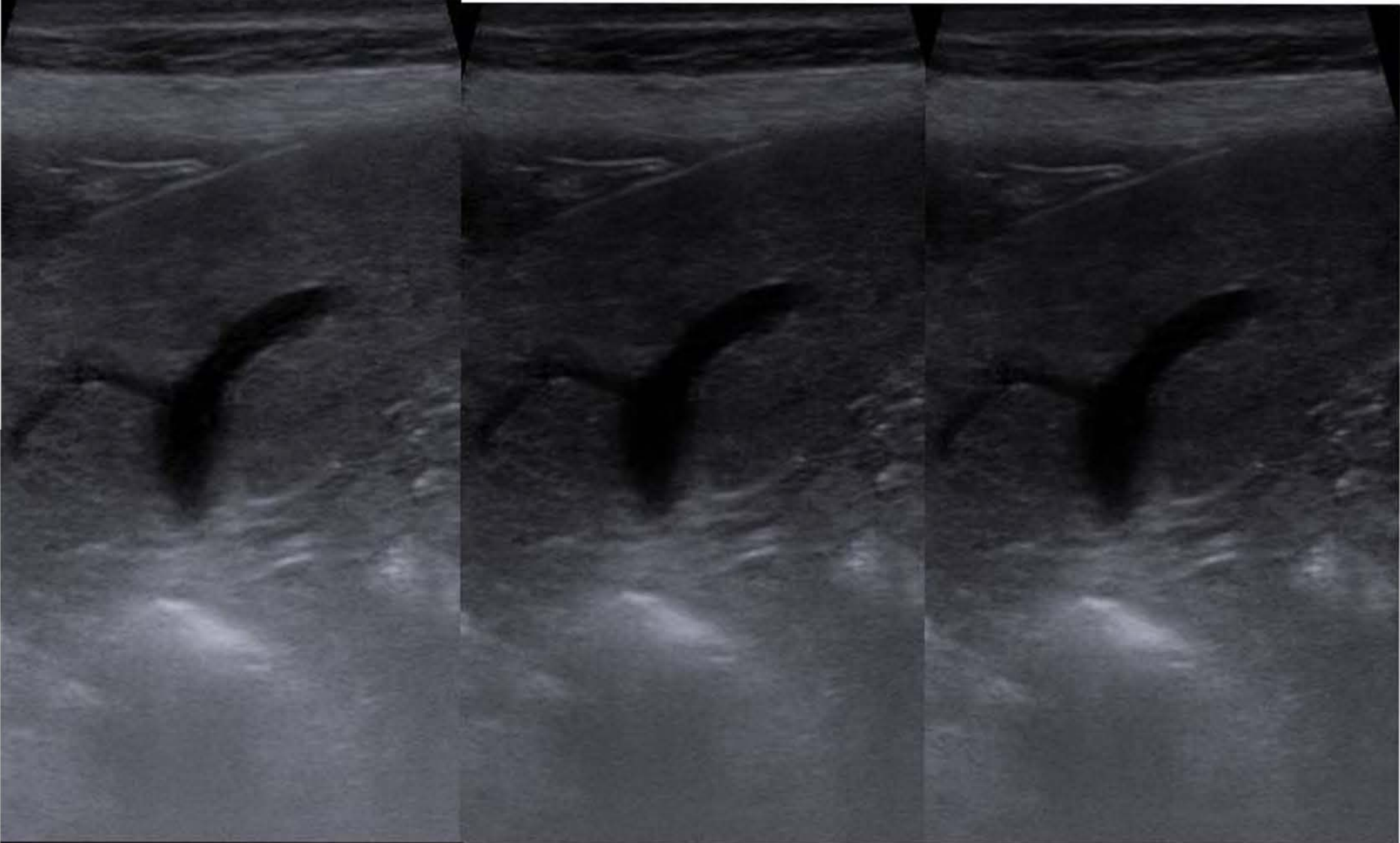
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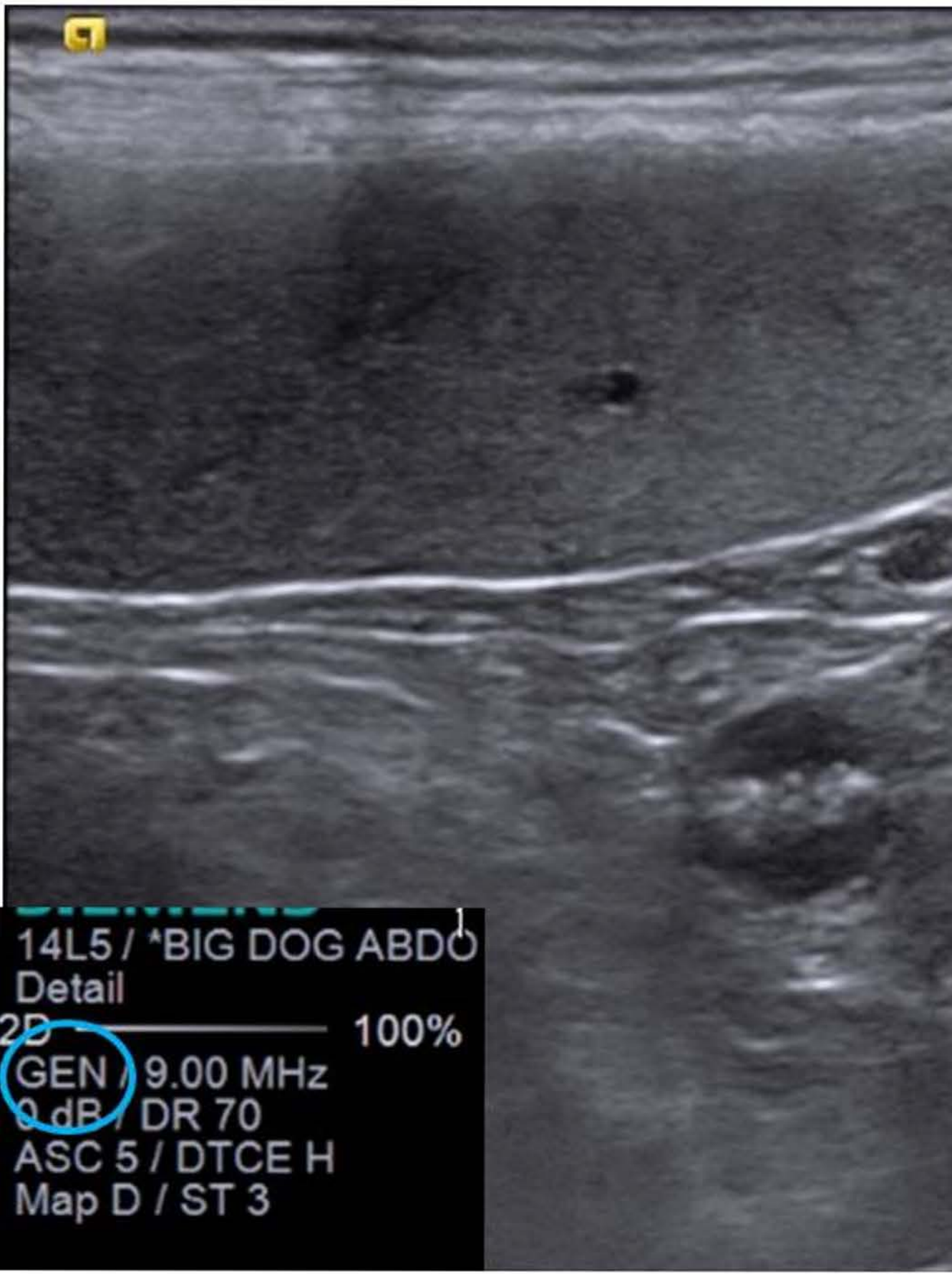
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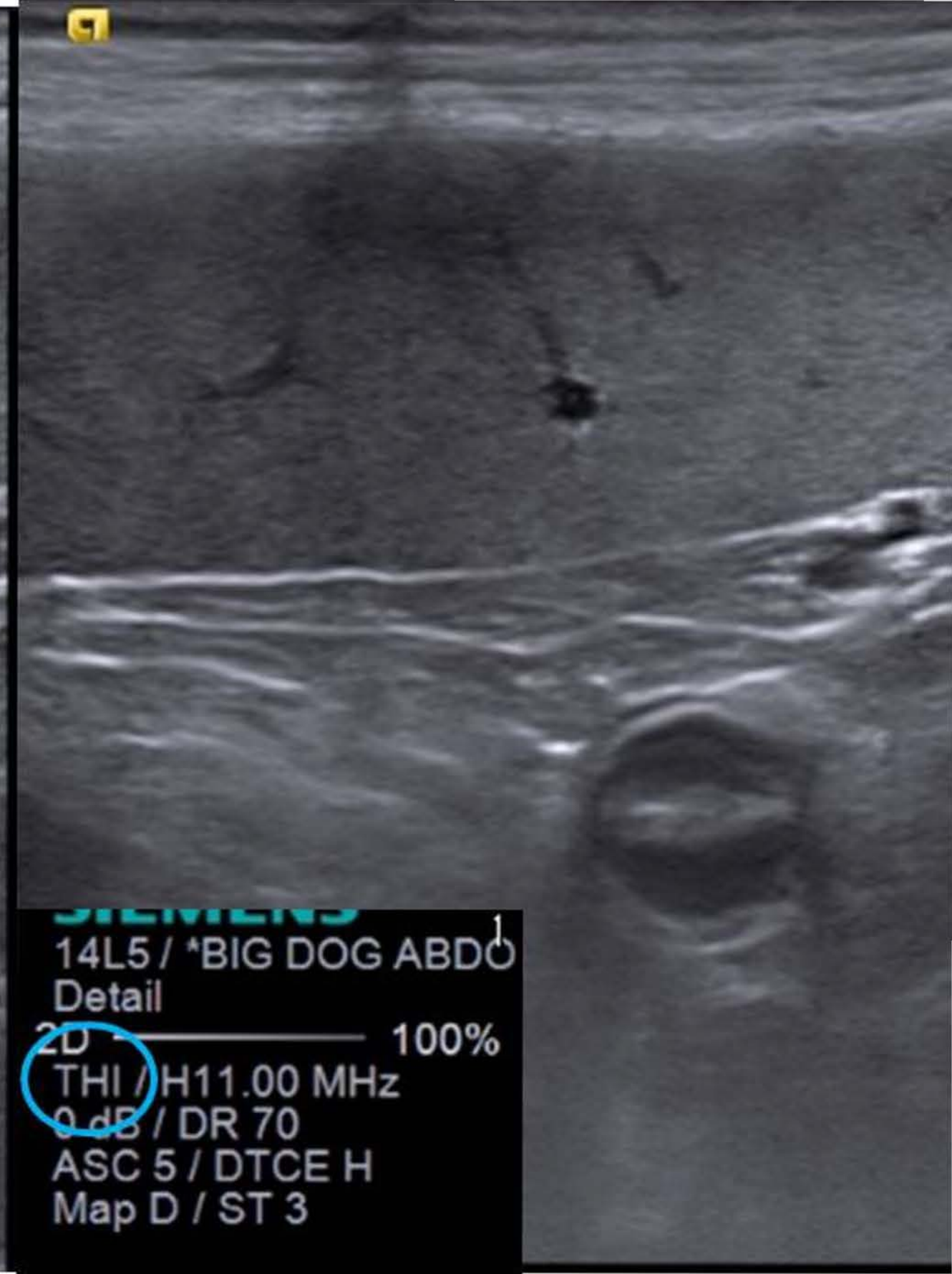








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Detail  
2D — 100%  
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0 dB / DR 70  
ASC 5 / DTCE H  
Map D / ST 3



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THI / H11.00 MHz  
0 dB / DR 70  
ASC 5 / DTCE H  
Map D / ST 3

